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SPATIAL THERMAL RADIOMETRY CONTRIBUTION
TO THE MASSIF ARMORICAIN AND THE MASSIF CENTRAL (France)
LITHO-STRUCTURAL STUDY

Jean-Yves SCANVIC
Bureau de recherches géologiques et minières
B.P. 6009
45 060 - Orléans cédex - France

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129, rue de l'Université
75 007 - Paris - France -

Report n°2	
Spatial thermal infrared radiometry contribution to the Massif armoricain and the Massif central (France), litho-structural study.	Report date March 1980
Jean-Yves SCANVIC	
B.R.G.M. Avenue de Concyr - B.P. 6009 45 060 - Orléans cédex - France	Contract or Grant N° HCMM 18
Centre national des Etudes spatiales 129, rue de l'Université 75 007 - Paris - France	Type II Report August 1979 - February 80

This report concerns an investigation started in April 1979 with N.A.S.A., the aim is to experiment the ability of infrared images obtained day and night over the Massif armoricain and the Massif central, France, with the HCMM satellite.

During the reporting period about 300 HCMM images has been received from N.A.S.A. and Lanion but only twenty are usable. For two scenes we have a same day and night infrared acquisition but in both cases quality of one of them (day) does not allow the realization of a thermal inertia map.

Even with this restricted number of usable images significant geological details can be mapped in the two concerned domains, lithology and tectonic. In the Causse plateau, in melting day, night and seasonal image interpretations it becomes possible to differenciate broad calcareous and dolomitic units. In the Massif armoricain some granite massifs, some of them being not observed on Landsat, have been delineated and neotectonic faults could have a certain thermal expression which is to be investigated.

SUMMARY

INTRODUCTION

ILLUSTRATIONS TABLE

Introduction

This report concerns an investigation started in April 1979 with N.A.S.A., the aim is to experiment the ability of infrared images obtained day and night over the Massif armoricain and the Massif central, France, with the HCMM satellite to delineate significant geological details.

This is a progress report, the second one.

Some images are visually interpreted and the geological mapping ability of thermal infrared is demonstrated.

I - Problems

The realization of the proposed investigation is favourably developping even if some problems occur. These problems concern :

- Cloud cover condition

The heat capacity mapping mission test-site cloud cover study based on Nimbus data allows investigator to determine the number of clear or less than 30 percent cloud cover cycles to be expected. Avalaible tables give 20 possibilities for the Massif armoricain per year and 33 for the Massif central. From U.S. we already have received 106 scenes (see fig. 1) over the two test sites : 65 visible day, 61 IR day, 40 IR night. But only 10 scenes are usable - From Lanion (France) we have recieved about 195 scenes - only 10 are acceptable, and five really usable (four night IR, two day IR, 1 visible).

This correspond to a period starting in may 1978, ending in september, 1979 i.e. 16 months (see fig. 2).

It is apparently more difficult than expected to obtain images with an acceptable cloud cover.

- Some day night and day infrared

In september 1979, HCMM acquired over the Massif central a day and night infrared, and day visible. Infortunatly the day image quality is poor, this scene being one of the two which could make possible the realization of a thermal inertia map. The second being acquiered in may 11, 1979.

- This second scene covers the southern part of France - but here also the day infrared image, on the overlapping area, is not really usable. Nevertheless we plane to ask NASA for a thermal inertia map on a very small uncloudy area.

- Day visible quality image

In general day visible quality image are poorly contrasted even if uncloudy Only two of them are usable but lineaments and geological boundaries interpretation, compared to the Landsat and Tiros one is very limited.

- Geometric correction

Compared to the Landsat standart scale occuracy easily making possible surimposition with topographical map, the HCMM products are not so good : deformations occur and scale changes between scenes are frequent.

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Figure 1 - HCMM DATA PRODUCTS RECEIVED - AUGUST 79 - JANUARY 80 (From US)

Scenes

1 -	A 0072	02230	3
	A 0093	130070	1
	-	130070	2
	A 0094	13250	1
	-	13250	2
	A 0118	01350	3
	A 0153	13240	1
	-	13240	2
	A 0115	13140	1
	-	13140	2
	A 0142	13190	1
	-	13190	2
	A 0200	02000	3
	A 0227	13010	1
	-	13010	2
	A 0073	13350	1
	-	13350	2
	A 0205	01540	3
	A 0035	02320	3
	A 0243	02040	3
	A 0141	02050	3
2 -	A 0038	12460	1
	-	12460	2
	A 0038	12440	1
	-	12440	2
	A 0033	01540	3
	A 0033	01550	3
	A 0097	01470	3
	A 0091	01370	3
	A 0113	12380	1
	-	12380	2
	A 0130	12550	1
	A.0075	01390	3
	A 0150	01350	3
	A 0034	13090	1
	-	13090	2
	A 0072	13170	1
	-	13170	2
	A 0018	12310	1
	-	12310	2
	A 0054	12430	1
	-	12430	2
	A 0198	01230	3
	A 0070	12410	1
	-	12410	2
	A 0033	12520	1
	-	12520	2
	A 0086	12380	1
	-	12380	2
	A 0102	01390	3
	A 0081	01500	3
	A 0145	12360	1
	-	12360	2
	A 0182	12231	1
	-	12231	2

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	A 0076	12520	1
	-	12520	2
	A 0055	13020	1
	-	13020	2
	A 0232	12540	1
	-	12540	2
3 -	A 0124	12430	1
	-	12430	2
	A 0209	01310	3
	A 0199	12370	1
	-	12370	2
	A 0193	12270	1
	-	12270	2
	A 0193	12260	1
	-	12260	2
	A 0091	01350	3
	A 0172	12400	1
	-	12400	2
	A 0172	12380	1
	-	12380	2
	A 0143	02400	3
	A 0141	13000	1
	A 0118	12320	2
	-	12320	1
	A 0099	02240	3
	A 0350	12460	1
	-	12460	2
	A 0142	13180	1
	-	13180	2
	A 0114	12570	1
	-	12570	2
	A 0167	08190	3
	A 0182	12250	1
	A 0082	13040	1
	-	13040	2
	A 0198	12210	1
	-	12210	2
	A 0145	01390	3
	A 0145	12370	1
	-	12370	2
	A 0071	12590	1
	-	12590	2

4 -

A 0195	02050	3
A 0072	02210	3
A 0034	13110	1
-	13110	2
A 0131	13140	1
-	13140	2
A 0093	13090	1
-	13090	2
A 0130	12570	1
A 0200	12570	1
-	12570	2
A 0131	02150	3
A 0034	13100	1
-	13100	2
A 0034	02120	3
A 0141	13020	1
-	13020	2
A 0045	13160	1
-	13160	2

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	A 0115 - 13160 - 1
	- - 13160 - 2
	A 0055 - 13040 - 1
	- - 13040 - 2
	A 0093 - 02100 - 3
	A 0024 - 13230 - 1
	- - 13230 - 2
	A 0024 - 13230 - 1
	- - 13230 - 2
	A 0035 - 02300 - 3
	A 0195 - 02050 - 3
	A 0141 - 13020 - 1
	- - 13020 - 2
	A 0025 - 13410 - 1
	- - 13410 - 2
	AA 0151 - 12400 - 2
	- - 12400 - 1
	AA 0062 - 13300 - 2
	- - 13300 - 1
	AA 0108 - 12450 - 1
	- - 12450 - 2
	AA 0142 - 02120 - 3
Bretagne	AA 0030 - 02370 - 3
Espagne	AA 0062 - 13300 - 2
Espagne	- - 13300 - 1
Corse - Sardaigne	AA 0108 - 12450 - 1
Corse - Sardaigne	- - 12450 - 2
Gascogne	AA 0184 - 13010 - 2
Gascogne	- - 13010 - 1
Espagne.	AA 0184 - 12590 - 1
Espagne	- - 12590 - 2
Bretagne	A 0046 - 13340 - 2
Bretagne	- - 13340 - 1
Loire	AA 039 - 02050 - 3
England	AA 053 - 03050 - 3
England	AA 0026 - 03000 - 3
	AA 0026 - 03020 - 3
Pyrénées	AA 0046 - 13320 - 1
Pyrénées	- - 13320 - 2
Alpes	AA 0166 - 12290 - 2
Alpes	- - 12290 - 1
Italy	AA 0166 - 12270 - 1
Italy	- - 12270 - 2
Massif central - Alpes	AA 0300 - 01100 - 3
Massif central - Alpes	AA 0300 - 12150 - 1
Massif central - Alpes	- - 12150 - 2
Alpes	AA 0379 - 01000 - 3
Méditerranée - France S	AA 0130 - 01590 - 3
Méditerranée	AA 0055 - 02050 - 3
Méditerranée	AA 0055 - 02070 - 3

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Figure 2 - U.S. and Lanion acceptable quality image

11	May	1978	3	Bretagne		U.S.	
11	May	1978	1,2,3	South of France		"	
26	May	1978	3	Bretagne	Poor	"	
29	May	1978	3	Massif central		"	
30	May	1978	3	Massif central		"	
17	July	1978	3	Massif central		"	
28	July	1978	3	Massif central		"	
19	August	1978	3	Western France		"	
3	September	1978	3	South of France		"	
4	September	1978	2	Bretagne	Poor	"	
14	September	1978	1	Bretagne	Poor	"	
–	–	–	2	Bretagne		"	
14	September	1978	1	Massif central		"	
–	–	–	2	Massif central		"	
15	September	1978	3	Bretagne		"	
24	September	1978	1	Massif central		"	
	November	1978	3	Bretagne		"	
	February	1979	3	Bretagne		Lanion	
5	July	1979	3	Bretagne		"	435 01 333
11	September	1979	1	Bretagne		"	504 12 224 6
–	–	–	3	Bretagne		"	504 12 222 8
–	–	–	2	Bretagne		"	504 12 224 7
11	September	1979	3	Orleans		"	
17	September	1979	2	–		"	

II - Products requierement

During the reporting period we have ordered, and received two C.C.T. one over the Massif central, the second over the Massif armoricain. They correspond to the following scenes :

AA 0093 - 02120 - 3
AA 0142 - 02220 - 3.

Processing are to be done by the "groupement pour le développement de la Télédétection aérospatiale" and concerns ;

- the optimisation of the photographic product
- enlargment possibilities

As an experiment temperature difference map and thermal inertia map have been requiered to NASA over a scene where day and night infrared exist but have not been acquiered during the same day. There is a 6 weeks interval but weather conditions are similar (summer season).

To ESA we have requiered, and received, radiometrically corrected images for five scenes. We also have requiered, and received one geometrically corrected images for two scenes.

We have at last experimented photographic enlargement on scene AA 0093 - 02120 - 3 (28 july 78), covering the whole Massif central. A four time enlargement (exactly to 1 million scale) is considered as a satisfactory one.

III - References data

The following documents have been used as a reference during the HCMM data interpretation :

- Tectonic map of France, 1 million scale (1980),
- Lineaments map of France, 1 million scale (1976), established from Landsat images,
- Hydrogeological map - Languedoc-Roussillon 1/200 000 "Les Grandes Causses",
- Sismotectonic map of France, 1 million scale (1979),
- Geophysical map , 1 million scale
- Thermal map of France (8 million scale, 1977),
- Bulletin de la Direction de la Météorologie nationale,
- Some Tiros N and Landsat images,
- Carte des formations superficielles, C.N.R.S. 1 million scale.

IV - Image analysis

4.1. - Comments on image quality

In general on images where clouds cover conditions make it possible interpretation the following remarks have been done :

. A - Day visible images contain a very small amount of significants geological data, compared with :

. infrared images, same scale
. or to Landsat visible images.

HCMM visible data *are not adapted to earth resources study.*

B - Day infrared images countain significant geological details : both lineaments and some rock units have a distinct thermal signature.

C - Night infrared images also contain significant geological data.

For both day and night infrared images seasonal conditions have an important effect on thermal signatures : *one can say repetitivity is an major parameter in thermal imagery interpretation.*

D - Reverse and normal prints submitted by N.A.S.A. make it possible, on some areas, to improve interpretation.

4.2. - Comments on some details perception

- On the sea

On night infrared image AA 0034 - 02130 - 3, 30 may 1978, a very large "piume" is correlated with "Etang de Berre" and correspond to a possible pollution. On the same image all coastal lake, both on mediteranean sea and Atlantic ocean are clearly visible,

On night infrared image AA 435 - 01333 5 July 1979, thermal differences in the "Baie de Seine" could correspond with turbidity or pollution (due to the Seine river) or with bathimetry. But, what ever the explanation is the phenomenon is very obvious (fig. 5 n° 10).

- On the ground

. In general lakes and pounds, even small, are more obvious on night infrared images but for rivers day infrared images make it possible a better interpretation.

In forested area night infrared make it possible geological differenciation cancelled by trees on day infrared images. On night infrared image acquired on july 5 (1979) above the Orleans region a thermal linear frontiere appears along the Beuvron, a small river : it delineates a cold zone to the north from a warm region to the south inside the Sologne forest. This detail corresponds to a Landsat lineament but the thermal frontiere which has not visible signature could correspond to the pleistocene and residual formations boundary (cf. Carte des formations superficielles - C.N.R.S.)

4.3. - Images analysis : comment on significant geological data

In this part comments only concern day and night infrared, even if for some exemples references from day visible images are given.

This analysis is presented in two parts :

. A/ The Massif armoricain
. B/ The Massif central

weather conditions are listed on fig. 3, fig. 3 b represents the weather station.

A - The Massif Armoricain

From the time we have published ther first type II report images received over the massif armoricain are all of poor or medium quality. Height images present a correct weather condition but only three show significant geological details.

a 1 - Nevertheless the interpretation confirms the importance given by thermal remote sensing to :

- the Sillon armoricain the main fault of the area
- the 140° north oreinted fractures which are revealed on night IR images by *warm thermal linear anomalies*.

Such faults are known by geologists : they are correlated with tertiary graben but not considered as very important. On the contrary they are considered as active faults by seismologists. Looking on published geological maps one can correlated some of them (see fig. 4).

1*- Sheet Rennes (1/80 000). This linear anomaly corresponds, in the Caune area, with the diabasis veins direction,

2 - Sheet Pontivy (1/80 000). Near Loudeac it extends known faults responsible for displacements of Devonian beds, into Paleozoic. This anomaly also corresponds with a change in the hydrographic pattern which flows, in the western part, perpendiculary to its.

3 - Sheet Pontivy (1/80 000). Near Saint-Vran the anomaly follows a small Pliocene basin and is a part of the Nort-sur-Erdre a gravimetric axis (Jaeger) which corresponds with a described Landsat lineament (Scanvic).

4 - Sheet Pontivy (1/80 000). Near Rohan it follows the direction of a small Pliocene basin and partly corresponds, toward south, with a Landsat lineament.

5 - Sheet Chateaulin (1/80 000). To the east of Rostrenem it corresponds with :

. important quartz and Kersantite veins (Plouguernevel on Pontivy sheet),

. the Persquen fault.

6 - Sheets Dinan and Avranches (1/80 000), the anomalies are paralell with the numerous mapped faults.

7 - Sheet Morlaix (1/80 000).

In the Plougonven area the anomaly corresponds with a known fault (Norht West of Planegat) hydrographic pattern and alluvial deposits reinforce..

These linear anomalies revealed by a *night infrared image* obtained in may 1978 (AA 0015 - 02550), are also visible, but no so clearly on an other image, AA 0142-02220 - 3 (september 1978). It also can be extended (point 3 for instance on image AA 435 - 01333) (night infrared, July 1979).

At last they are not visible on *day infrared images* , even if they present good weather conditions (AA 509 - 12 112, 17 septembre 1979).

a 2 - On an other hand, HCMM data seems to have a certain ability to discriminate some kind of granits in the Massif armoricain.

. The circular shape of the western part of the Quintin granite, revealed by Landsat images (Scanvic) is obviously correlated with a thermal ring, coldest than the environment (Fig. 4 - 8). The eastern part, as on Landsat images

* Numbers refer to figure

Fig. 3 . - <u>WEATHER CONDITIONS</u>

DATE	LOCATION	MINIMUM TEMPERATURE*	MAXIMUM TEMPERATURE	RAIN	SUN
19, August 1978	Western France	9 - 14°	21 - 27°	No rain from august, 17	good
15, Sept. 1978	Bretagne	6 - 12°	18 - 22°	No rain from august, 12	good
5, July 1979	Bretagne	6 - 12°	19 - 25°	No rain from July, 1	good
17, July 1978	Massif central	8 - 16°	26 - 34°	No rain from July, 12	medium
28, July 1978	Massif central	11 - 16°	26 - 33°	No rain on 27 and 28	good
14, July 1978	Massif central	3 - 10°	21 - 25°	No rain from sept 12	good
24, Sept. 1978	Massif central	3 - 12°	21 - 27°	No rain from sept 21	good
11, May 1978	Bretagne	8 - 10°	15 - 17°	No rain	poor
30, May 1978	Massif central	12 - 17°	13 - 23°	No rain from may 29	poor
27, Febru. 1979	Bretange	3 - 17°	8 - 10°	No rain	poor

* Degré Celsius

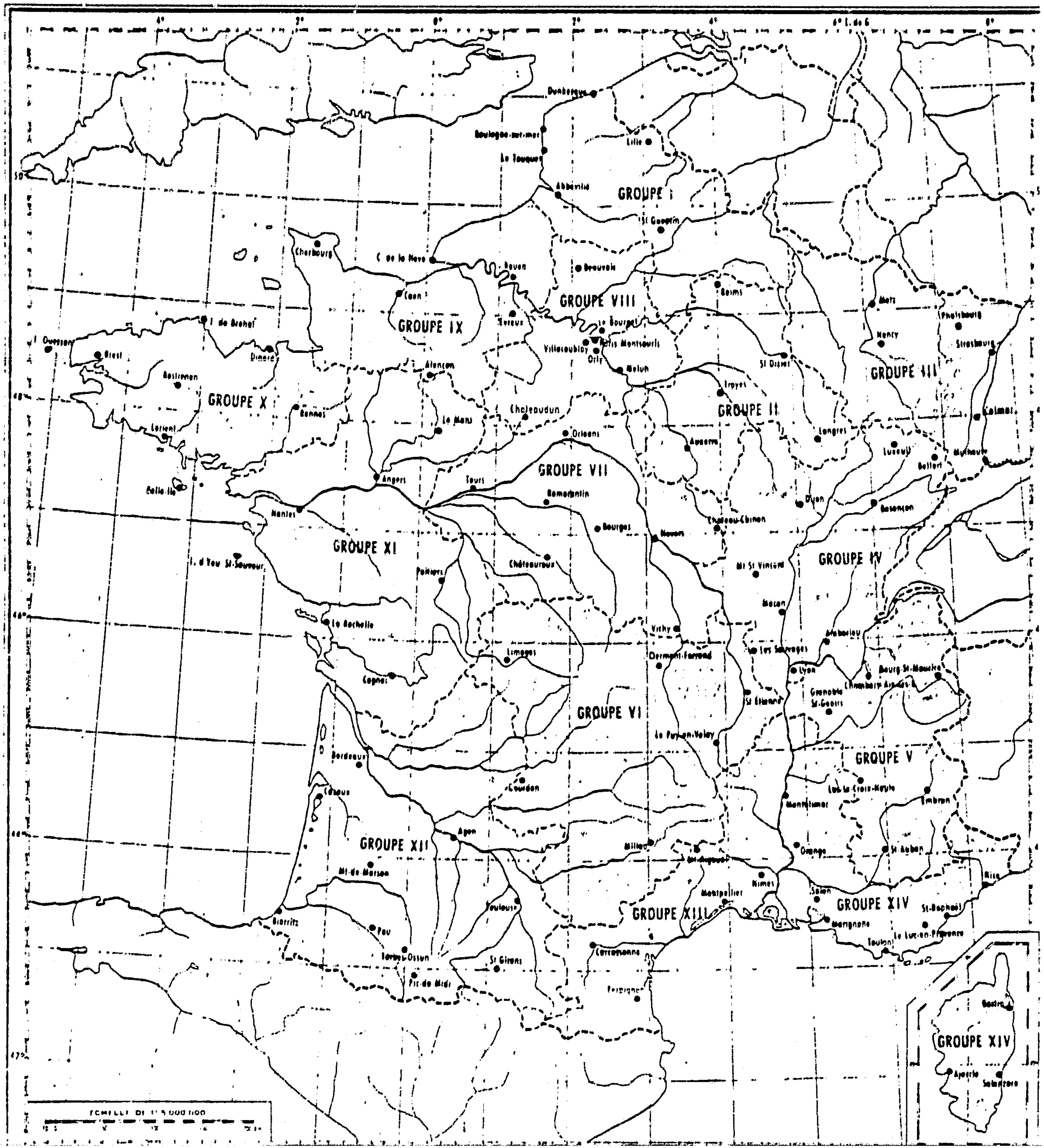
Supplément au

RÉSUMÉ MENSUEL DU TEMPS EN FRANCE

Mois d'Août 1979

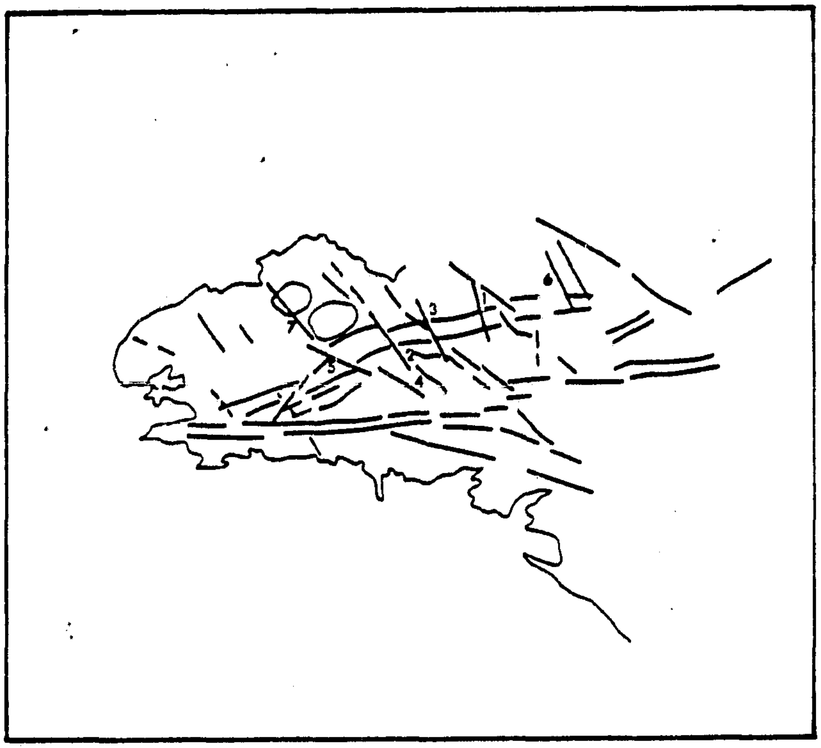
BULLETIN DÉCADAIRE D'OBSERVATIONS QUOTIDIENNES
du 1er au 10 inclus

Emplacement et répartition des stations



HCMM STRUCTURAL INTERPRETATION

Of the Massif Armoricain (France)



LEGEND

Thermal linear anomalies

Coastal line

Plouaret and Quintin granit

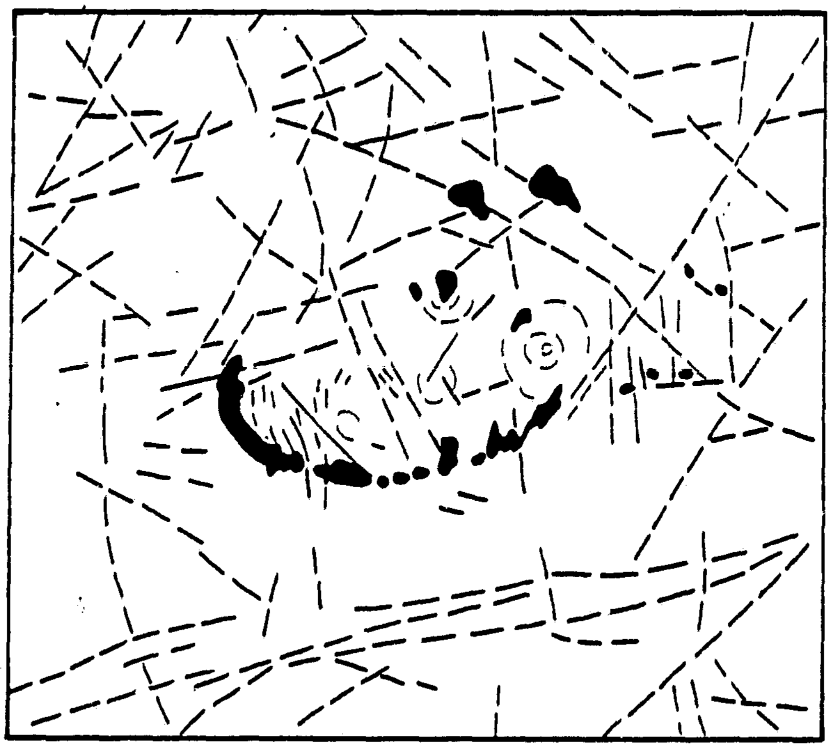
SCALE: ± 1/4 000 000

Fig. 4

MASSIF GRANITIQUE DE QUINTIN

CARTE DES LINEAMENTS DE SATELLITE

(d'aprés Landsat)



LEGENDE

Linéament

Elément stuctural

Forêt

ECHELLE : 1/500 000

Fig. 4b

does not appear . Field works confirm a change in granite from west to east (Fig. 4b), could be existed.

. North of Quintin a similar circular thermal anomaly corresponds with the Plouaret-Belle Isle en Terre granite (Fig. 4b). From the 1 million scale geological map of France they have the same age and petrography.

Both of them are only visible on *day infrared image* :
AA 0131 - 13 140 - 2 (4 september 1978) and AA 509 121 12 (17 september 1979).

. South of the Loire river, the Mortagne granite massif is revealed on images :

AA 0115 02100 - 3 19 august 1978, by alternating warm and cold circular thermal anomalies and

AA 435 01333 - 5 July 1979 by similar details.

Such thermal differenciations can be approximatly correlated with the main petrographic differences (J-P. Renard).

Until now, this granit is only *visible on night infrared images* and it doesn't *correspond with significant details on Landsat.*

a 3 - H.C.M.M. image AA 435 0133 (July 3, 1979) acquiered by the Earthnet Lanion station (France) is a night infrared image which contain numerouns significant geological data (fig. 5).

Over the Massif armoricain thermal linear anomalies can be very often correlated with known geological details :

1 - Thouarce - Montreuil Bellay fault,
2 - Gravimetric discontinuity
3 - Savenay micashistes faults boundaries,
4 - The Noirmoutier island is not visible
5 - Niort fault,
6 - La Marche fault,
7 - La Vilaine fault,
8 - Nogent-le-Rotrou fault.

The sillon armoricain, a main fault, correspond to a thermal difference the north-eastern limb being coldest thant the south-western limb (9).

B - <u>The Massif central</u>

. Lithology

Taking in acount some of the significant geological details revealed by thermal differences our purpose is, by analysing each of the interpretable images we got, outlined the evolving character of the H.C.M.M. data. To do that we have selected some obvious geological features:

The Levezou basic rocks
The Causses limestones plateau
The Mont Lozere granite
The Cantal volcanic dome
The Limagne valley, tertiary in age
The Berry, Jurassic anc cretaceous limestones
The Bayonne Miocene
The Tertiary Libourne deposits.

. / .

NIGHT INFRARED IMAGE INTERPRETATION

LEGEND

SCALE : ± 1/4 000 000

Thermal linear anomalies

Coastal line

Fig . 5

ORIGINAL PAGE IS
OF POOR QUALITY

Fig. 6 - THERMAL ROCKS UNIT SIGNATURE

	30 May 78/3	17 July 78/3	28 July 78/3	19 August 78/3	3 September 78/3	14 September 78/2	24 September 78/2	February 70/3	11 May 79/3	11 May 78/2
…vezou	C	C	C	C not obvious	C	C, N	C but not re-vealded	Clouds	C	N, C
…usse	C	C	C	not on image	C	W (part of)	W (part of)	Clouds	C	W
…nt Lozere	C	C	C	not on image	C	C	C	Clouds	C	Clouds
…ntal	Clouds	C and W		W on southern limit	Not clear	Coldest on top Cold on flanc	C	Clouds	C	Top C (snow) Flancs n-M
…magne	M	M	M W	M, not obvious	M	West Limagne W	West Limagne W	Clouds	M (E and W)	"
…rry	N W	N W	N W	N (M-W)	Not on image	Not on image	W X	N C	Not on image	"
…yonne	N M	Clouds	Clouds	W, very obvious	Clouds	N - C	Not on image	Not on image	Not on image	"
…bourne	N W	Clouds	N C	N	N	C	Not on image	Clouds	Not on image	"

	11 Sept. 79/3	12 Sept. 79/3	12 Sept. 79/2	17 September 79/2	5 July 79/3	Landsat, 12 April 76	March 73 Landsat Mosaïque	Tiros N Visible 5 Sept. 79	Tiros N thermique 5 Sept. 79	Meteosat Visible 30 July 75
…vezou	Not on image		Clouds	Clouds	Not on image		Not visible	Not differen-ciated	Not visible	
…usse	"		"	Clouds	Not on image	Visible	Visible	"	Poorly diffe-renciated	
…nt Lozere	"		"	Clouds	Not on image	Not visible	Not visible	"	Not visible	
…ntal	"		Top cold Flanc W	Clouds	Not on image	Visible	Snow	Visible	Poorly diffe-renciated	
…magne	Clouds		W	W (West) M (Ambert)	Not on image	Not visible	Not clear	Not clear	W	
…rry	N M	N W	W but cloudy	W	N C	Visible	Not visible	Not visible	W	Visible
…yonne	Not on image	Not on image		Clouds	Not on image	Not visible	Not visible	Not visible	Not visible	
…bourne	Not on image	N M	C (also on visible	C	Not on image	Visible	Not visible	Visible	C	Visible

C = cold,
M = Medium,
W = Warm,

N = not revealed by thermal signature
NC, NW not revealed but C and W indicate the relative ambiant temperature

The thermal evolving signature of each of them is analysed in fig. 6.

From this figure we can conclude :

- The Levezou basic rocks, coldest than the surrounding at night, whatever the season is, are not revealed during the day being as cold as the other rocks.

- The Causse limestones plateau is generally cold during the night but warm during the day this making possible some differenciations at night in July 28 : the eastern part is cold, the western part is warm, not distinct from the surrounding.

The differenciations seems to correspond (hydrogeological map at 1/200 000) with the upper and medium Jurassic beds (to the east) where *dolomitic rocks* are more important, and with lower jurassic beds, to the west, *where limestones* are mostly outcropping (J 1). All over the Jurassic units (J1, J2, J3) including the Rodez extension, is revealed by a warm thermal anomaly.But in september 78, 14, also during the day, the warm anomaly is restricted to the eastern part (J1, J2) which is also separated in two units, one to the north, the second to the south. This observation, not explained on published geological maps is corroborated by Landsat image 21 177, 19 september 1976 : a similar differenciation is visualized but on band five only.

- Mont Lozère granite.
Cold during night and day, the granite can be differenciated only *during the night* from the Causse limestone which are overlaying it. This can be also observed on Landsat image, bande 5 and then seems to indicate vegetation is the main revelator. On Goodyear side looking radar (3 cm) roughness also allows the differenciation.

- The Cantal volcanic massif.
This massif is composed by two units . The topography make it possible the differenciation into a warm anomaly (volcanic projections) and a cold unit (lave flows), during the night, A perfect circular shape outline this tertiary volcano. The thermal seasonal evolving of this massif is not clear. Apparently there is no day-night inversion but the contrast between the two units, along the year is levelled.

- The Limagne valley, medium cold at night is warm during the day. The Ambert section, a small tertiary basin, doesn't change its apparent temperature between day and night : this can be due to size or soil-vegetation association.

- The Berry limestones.
Whatever the season is this unit, in its Jurassic part can not be differenciated from the surrounding rocks during the night, all of them being warm.

During the day, in september, the Berry Limestones are vizualised by a warm anomaly and Tiros N image confirms this observation. On visible image one can observe :

Landsat	March 1973	nothing - no vegetation
Landsat	April 1976	Berry limestones - vegetation starts
Tiros N	Sept. 1979	nothing - no vegetation
VHRR	July 1975	Berry limestones - vegetation.

If vegetation is the revelator in the visible part of the spectum soil and associated lithology are responsible for the thermal anomaly during the day.

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- Bayonne Miocene.

It is difficult to comment this thermal anomaly, which correlates very well with geology, because we only have it on one image, in August : it, seems to be a seasonal effect, never observed during the day even on the visible Landsat or Tiros N images.

- Libourne tertiary unit.

This unit is not differenciated on night infrared images and is separated from surrounding rocks through a cold thermal anomaly during the day. It is also on Landsat and Tiros N images during the vegetation period, but not in march when soil can be observed. Then a such anomaly revealed the vegetation associated with the geological unit.

These examples demonstrate the evolving character of the geological detail thermal signature : some of them, if not all of them are vizualised because they thermically move from day to night and during the year. Then it seems possible, even without preparing thermal inertia map, to separate significant geological details. Thermal satellites are very well adapted to geological mapping but weather is a limitating condition for two reasons :

1 - Clouds cover is important most of the time,

2 - in three occasions we have correlated some very important thermal differences with a change between two regions having a that time, a weather temperature difference. This is very clear on night image AA 0093-02120 (July 78) where a 160 km thermal difference which exist along the Rhone valley correspond with the change between the Ardeche mediterranean basin (warmer) and the Atlantic basin (colder), with a good accuracy we have appreciated on the enlarged image (Scale 1 million). Note this difference runs across a schist unit ie schistes of Ardèche.

At last if topography, vegetation and or the soil-rocks couple are responsible for the main thermal signatures the seasonal and diurnal observations make it possible to separatly appreciate each parameter and then to take in account the only one significant geological details.

Tectonic

In the first progress report (Scanvic, september 79) we have presented a thermal linear anomaly map issued from one single image. The interpretations of the new images received have been gathered and the more important have been selected and their thermal signature analysed (fig. 7). From this analysis some remarks can be presented :

1 - It exist two kinds of linear thermal anomalies :

. linear warm or cold anomalies inside a cold or warm area
. linear frontiere between a cold and a warm zone.

2 - In most cases the first kind of linear anomalies corresponds with faults. These anomalies, exepted if the quality image is not good, are always visible on the different scenes we have. But not all the ground known faults are represented by this kind of anomalies and a reflexion starts on this remark which could be important if for instance neotectonic is partly responsible for this special signature.

3 - Two linear frontieres between a cold and a warm zone have been studied in more details. The first one correspond to the south-western extension of the Noyant fault, considered by geologist as a Sillon Houiller part. This extension is quite visible at least on three HCMM images. Until now this is not explained by lithological change neither by faults even if they are visible on Landsat images. At last it exactly corresponds with an important change in the hydrographic pattern, rivers running to the west and to the east on each side of

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Fig. 7 - SOME LINEAR THERMAL SIGNATURES

	17 July 78/3	28 July 3	19 August 3	14 September 2	24 September
Sillon Houiller	W (inside C)	W (inside C)	W (inside C)		
Villefranche	W (inside W)	W (inside W)	W (inside M)	Discret boundary between two cold zones	Boundary betw 2 thermal zone
Argentat fault	Limit W – C	Limit W – C	Not visible		
West Limagne fault	W	W	Not visible		Limit C – W
La Marche fault	W	W	W (limit W – C)		
Saint-Etienne	Limit C – W	W	Not on image	W (limit W – C)	C
Brevenne	W (inside W)	Not visible	Not on image	C	C
Montbrison	W (inside W – C)	W (inside W – C)			Limit C – W (s extension)
East Limagne	W (inside W – W)	W (inside W – C)			Limit C – C
Margeride – Mont-Dore	Graben , W inside C	W	Local graben (W inside C)	C Graben	Graben C
Noyant	W in limit C – W	W (inside C – W)	Limit C – W		
Sillon Houiller North extension	W (inside M – W)	W (inside W)	W (inside M)	-	C (inside W)

C = Cold
W = Warm
M = Medium

the frontiere (to the Sioule river on the east, ther Cher river on the west). The meteorological map of August 1978 and July 1979 (isohyetes) outline a water precipitation differences paralell to this anomaly. Then if we cannot excluded *a tectonic explanation the meteorological point of view is to be taken into consideration.*

The second anomaly corresponds to the southern limit of the Massif central, Faults are known locally but the frontiere also follows a change in the hydrographic pattern, rivers going to the Rhone on one side, to the Garonne on the other side. Here also the meteorological influence is to be taken into consideration.

CONCLUSIONS

This reporting period make it possible to reach some conclusions in the two concerned domains, lithology and tectonic.

- Rocks units, even if note outcropping and soil covered (Berry) may have a thermal signature which has been observed

. for some granit massifs : Quintin, Mortagne, Mont Lozère
. in the Causse plateau where a limestone-dolomie difference is vizualised.
. under forest the signature is levelled by night observation.

These thermal signatures can be observed :

. by a change between day and night, and then it corresponds to different thermal inertia which can be apprehanded by visual interpretation,

. by a seasonal change, due to a change in the associated soil and vegetation,

. but climatology may create thermal differences, sometimes very important (Ardèche) uncorrelated with geology.

At last rocks form with soil cover and associated vegetation a thermically moving unit : a single image brings out significant geological details but diurnal and seasonal images used together bring more. It exist :

. a day and night complementary
. a seasonal complementary

which seem more important than the one discovered in the visible part of the spectrum.

- Linear thermal anomalies are of two kinds, linear inside a thermal zone, cold or warm, and linear frontieres between cold and warm units.

. The first one always correspond to faults. In this early stage it appears lineaments, in the global sense admitted for Landsat interpretation, are not visible on HCMM images, linear being restricted to faults. In the Massif armoricain some of the visible faults, correlated with the Alpine direction, are considered as secondary by geologists but very important for seismologists. They are only visible during the night through a warm anomaly. A such observation can be considered as a significant result to be evaluated in term of neotectonic.

. The second kind of linear anomaly could correspond with faults but physiography and meteorology may have a role to play in. Nevertheless the explanation is they have to be investigated mainly some of them which may have depend the season, the two appearences (Sillon armoricain).

At last, even with a restricted number of HCMM thermal images geological significant details can be extracted by using day and night and seasonal data. One of the main question is to know what is the part due to resolution and scale in this result.

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